Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/US05/008817

International filing date: 16 March 2005 (16.03.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/553,637
Filing date: 16 March 2004 (16.03.2004)

Date of receipt at the International Bureau: 20 April 2005 (20.04.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

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APPLICATION NUMBER: ***60/553,637***
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. EV 331740420 US

INVENTOR(S)

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☐ *Additional inventors are being named on the ___ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

AUTOMATED FOAM INDEX TEST INSTRUMENT, RELATED SYSTEMS, METHODS, AND A KIT

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS ***(check all that apply)***

☑ Specification *Number of Pages* 40

☐ CD(s), Number

☑ Drawing(s) *Number of Sheets* 2

☑ Other (specify) POSTCARD

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☑ Applicant claims small entity status. See 37 CFR 1.27.

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Respectfully submitted,

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Date 3/16/04

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Docket Number: **1284-001 P**

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

Docket No. 1284-001P

Automated Foam Index Test Instrument, Related Systems, Methods, and a Kit

This is a PROVISIONAL application filed under 35 U.S.C. Section 111(b) and intended to comply with the requirements of 35 U.S.C. Section 112.

Copyright Statement

Technical Field

The present invention relates generally to monitoring or controlling foaming and, more particularly, to an instrument, related systems, methods, and a kit for use in characterizing, monitoring, or controlling any process involving foam or an object (gas, liquid, or solid) susceptible to foaming.

Background of the Invention

Foams or emulsions (hereinafter collectively referred to as "foams") are ubiquitous in various processing operations. Sometimes, foam creates or provides certain desirable product characteristics, such as a specific consistency of food or taste in a beverage (e.g., beer), and is thus considered advantageous. Other times, foam is an undesired byproduct, such as during wastewater treatment. Likewise, foam is sometimes not a problem if present as long as it is monitored and kept in check.

Many systems and processes rely on human intervention for monitoring and controlling foaming. For instance, the concrete industry and associated cement, mineral admixture and chemical admixture supplier industries, use visual, subjective measurements or ASTM methods to determine both the level to which air entraining agents, or "AEA's," are to be dosed into concrete to meet construction specifications and to gauge stability and the foaming characteristics of AEA's. AEA use is mandated by state and U.S. federal transportation agencies in concrete highway and bridge construction and in building construction standards (e.g., ACI 318 Building Code) whenever temperatures below 32°F are experienced.

In order to gauge the proper amount of AEA to be added to concrete mix, tests are manually performed beforehand on a sample to assess the foam stability. This testing involves a visual inspection of the sample to monitor the behavior of the foam, such as the amount of bubbles breaking in the foam over a given time period, to assess whether more AEA must be added (in which case the test is repeated until the appropriate amount is

determined). Obviously, this is not only a time consuming, laborious process that can lead to frustration, but also a highly subjective one that often leads to an inconsistent end product.

Similarly, under current industry-wide practices, wastewater plants manually measure and monitor the level of foam created during the aeration portion of the treatment process. This requires workers to visually inspect, manually extract, and perform optical measurements on water samples to quantify the cause of the excessive foaming (which is typically microbial in nature) and take appropriate corrective measures. This is obviously a laborious undertaking involving careful sampling and analysis of the resulting data. Moreover, reestablishing a proper balance of microbes or other operational parameters of the system can take up to one week. This time delay increases the probability of excessive foaming in the interim, which can lead to a deleterious and hazardous overflow of sewage-laden foam requiring emergency measures to control or contain.

Accordingly, the need exists for an automated manner in which to monitor and/or control foaming, whether created for beneficial purposes or otherwise. The approach taken should be capable of monitoring the foam with the ability to make an objective characterization. Appropriate control measures could then be taken based on the characterization, such as to increase, decrease, or stabilize the foaming. Together, this monitoring and control would decrease the amount of manual labor and subjectivity in characterizing the foam, thus providing a significant savings in terms of time and money in a myriad of commercial and industrial processes.

Summary of the Invention

The present invention relates to the monitoring and control of a process involving foaming or an object susceptible to foaming, including by detecting one or more acoustic emissions of the foam using a passive sensor. The detected emissions may then be used to generate a response, such as one to control (e.g., increase or decrease) the foaming. Corresponding methods, systems, and test instruments are also disclosed, as is a kit including a passive sensor and instructions for using it in a foam monitoring or control process.

Detailed Description of the Invention

Combined reference is now made to ***Exhibit A***, herein incorporated by reference, and Figure 1, which in block form diagrammatically illustrates one embodiment of the automated foam index test instrument 10 of the present invention. In its most basic form, the instrument 10 includes a sensor, such as a passive acoustic sensor 12, positioned in or adjacent to a given object, such as a volume of a fluid or liquid 14, and an associated controller 16. In one embodiment, the automated foam index test instrument 10 measures the acoustic emissions generated by an emulsion or a foam associated with the surface of the liquid 14, but use with various types of solids and gases susceptible to foaming is also possible.

As is known in the art, foam consists of cellular structures in which films or cell walls define outer limits of individual bubbles within the foam. One example of a foam would be soap bubbles on the surface of water. Due to the instability of the foam, the bubbles often "break up" or burst. As

the foam "breaks up," it emits one or more transient elastic waves or energy comprising an acoustic emission. Bubble bursting illustrates one example of where acoustic emission occurs and can be monitored by the present invention. The foam also generates an acoustic emission when liquid drains within the cell walls of the foam, such as while under the influence of gravity. Additionally, the transport of a gas within a bubble through its cell wall or a pin hole into an adjacent bubble also generates an acoustic emission.

To detect and characterize the foaming, the sensor 12 may detect or measure all of these modes of acoustic emission and communicate this data to the controller 16, such as via an output signal representative of the acoustic emission(s). In the preferred embodiment, the sensor 12 is positioned anywhere in, at or near (collectively "adjacent") the liquid 14, and preferably sufficiently close such that it is in acoustic communication with any foam present. In such position, the sensor 12 is thus able to receive passively the acoustic emissions within a given frequency range (e.g., 20 Hz to 1 Mhz).

A "passive" sensor is distinguished from an "active" one in which an acoustic signal (usually ultrasonic) is both transmitted and received by the sensor. The sensor 12 may comprise: (1) a contact sensor mounted onto a vessel, container, support, pipe or other solid structure; (2) a hydrophone immersed within a liquid, gas-liquid mixture, gas-bubble mixture, solid-liquid mixture, or solid; or (3) a microphone contained within a gas. Exemplary passive contact sensors suitable for use in detecting acoustic emissions are manufactured and sold by Physical Acoustics Corporation,195

Clarksville Road, Princeton Junction, NJ 08550 under various model numbers, including R15I and R1.5I.

The root mean square level of acoustic emission from collapsing bubbles correlates to the amount of energy radiated as the bubbles collapse. Generally, high emission intensity relates to high bubble breakup activity and low emission intensity relates to low bubble breakup activity or high foam stability. For example, in the case of an aerated water-ethanol surfactant, this mixture generated a high emission intensity in the 25-70 kHz range related to bursting bubbles. Additionally, the mixture generated an emission in the 200-300 kHz range during inter-bubble diffusion and liquid drainage. The sensor 12 may detect these discrete acoustic emissions and communicate this data to the controller 16.

The controller 16 receives the emission data, which may be a corresponding electrical output signal (e.g., voltage), from the sensor 12. The controller 16 may consist of a signal processor and/or amplifier for increasing the strength of the signal received and a computer system operational for recording the emission data. Thus, the sensor 12 may detect representative acoustic emissions of a foam and produce corresponding signals relating to these acoustic emissions, including intensity and number (hits),associated waveforms and frequencies, amplitude, total energy, rise time, pressure level, etc.

For each process or system utilizing the foam index test instrument 10, the controller 16 may be programmed to identify desired characteristics for the particular system. For instance, during a certain

process, a user may wish to only monitor the intensity of the acoustic emission(s). Therefore, the controller 16 may be programmed only to monitor this single characteristic using the output signal provided. Additionally, the controller 16 may monitor several characteristics and analyze the resulting data with respect to changes over time.

Besides monitoring and/or recording this information, the instrument 10 may be used to automatically control the foaming. For example, a predetermined or known threshold value representing an acceptable level of foaming for the particular system being monitored may be provided to the controller 16. The threshold value may be the achievement or loss of a certain intensity level, number of hits, and/or frequency spectral characteristics, at any particular time or over a given period. The user may determine this threshold value from previous experiments yielding empirical data, mathematical calculations, or otherwise. Preferably, the threshold value is set such that the foaming may be controlled before, after, or when a predetermined desirable or undesirable level is achieved.

Once set, the controller 16 may be programmed to actuate a feedback response upon receiving acoustic emission values approaching or exceeding the predetermined threshold value. This response may include any type of user-identifiable output, such as sounding an alarm or light. Alternatively, the response may simply involve automatically taking measures to control the foaming, such as by adding an anti-foaming agent, reducing the liquid level, halting the corresponding process creating the foaming, or otherwise. Exemplary controllers and the associated control software for use

with passive acoustic sensors are also marketed by Physical Acoustics Corporation.

In addition to using a single sensor to monitor foaming via acoustic emissions, it is also possible to make simultaneous or concurrent use of multiple sensors to determine the relative location of foaming activity. For example, multiple sensors can be placed adjacent to an object, such as a volume of liquid, susceptible to foaming. Differences in the output signals may then be used to determine the location of foaming "hotspots," which may correspond to a non-uniform consistency or concentration of reactants and products. Appropriate adjustments or corrective measures can then be taken

Reference is now made to the following practical examples, which are in some instances prophetic. Moreover, although described with particularity, these examples should not be viewed as limiting the scope of the invention.

EXAMPLE 1 - CEMENT/CONCRETE FOAM INDEX

Figure 2 illustrates schematically how the automated foam index test instrument 10 may be used in conjunction with a known process involving a mix 15 used in forming concrete having a desired set of characteristics.

Initially, a baseline amount of the additives, such as an AEA comprising the sodium salt of dodecylbenzenesulfonic acid ($C_{12}H_{25}C_6H_4SO_4Na$) is added to a test sample of the concrete mix 15, which may already include water. A sensor 12 associated with this test sample 15

communicates with the controller 16 to relay output signals indicative of acoustic emission(s) as the AEA is added. In this instance, the controller 16 receives the number of hits (i.e., the energy pulses detected by the acoustic sensor 12, such as may be created as bubbles burst) over a period of time, and may display this information on a suitable device, such as a monitor.

By recording the change in the number of hits as the total amount of AEA increases, the user can determine if the optimal amount of AEA has been added. The AEA may be automatically added by the test instrument 10 from a source 17, such as a titrator, or it may be manually added. Moreover, an agitator such as a mechanical shaker or stirrer (not shown) associated with the mix 15 may receive output signals from the controller 16 in order to mix the newly added AEA.

In addition to recording the number of hits, the controller 16 may record the sound pressure level and the acoustic frequency. Monitoring or analyzing specific frequency ranges and detecting their intensity versus time or other process variables assists in defining the interaction of AEA with the concrete and the amount of AEA to be added for establishing the correct amount of entrained air that is specified or called for by code, regulation and/or condition to which the concrete is exposed.

Figure 6 of ***Exhibit A*** illustrates one experiment conducted using Portland Cement. After AEA addition, the spectra show that foam break-up produces both narrow bands and a broadly-distributed signal. In particular, after adding1 ml of an AEA, a narrow emission band was observed at 1,750 Hz; it broadened and moved to 2,150 Hz upon adding 2 ml of an

AEA, and again broadened and moved to 2,950 Hz upon adding 3 ml of an AEA. After 4 ml AEA, no narrow bands were observed and the background emission level was very low. An average, integrated signal intensity over the 0-to-15 kHz frequency range is plotted in Figure 7 of ***Exhibit A***. The intensity increased rapidly as the amount of the AEA was increased up to 3 ml; between 3-to-4 ml of the AEA, the integrated intensity dropped by over 80%.

These data show that the intensity of the acoustic emissions increased with the increased addition of the AEA, and then decreased dramatically when stable bubbles were created. This pattern originates from: first, with a very weak foam, the primary sound intensity comes from the breaking of very few bubbles or background noise, i.e. low-to-moderate intensities; second, as the amount of foam increases but is still unstable, the sound intensity increases dramatically from a plethora of unstable bubbles; third, the foam stabilizes at which point the emitted sound decreases dramatically.

The visual foam index procedure gave an average value of 3.5 ml. A value between 3-to-4 ml (Figure 7) was also obtained from the acoustic emission results. Therefore, these data provide credence to using acoustic emissions as a way to automatically measure the foam index of cements. Furthermore, they suggest that foam or emulsion stabilities in other materials or applications should also be measurable using the arrangement shown in Figure 1.

According to ASTM C 260 Standard Specification, manufacturers are required to certify the 'age' of AEA's supplied to users. Liquid AEA's have a limited shelf life, after which their foaming characteristics degrade. Therefore, AEA manufacturers continually check their stock and look for inexpensive, alternative chemistries that have acceptable foaming properties and long shelf life. It is appreciated that such qualification testing of AEA formulations is common practice and performed by manufacturers to compare and quantify AEA foaming and air entraining properties relative to an expensive and industrially-accepted standard, obtained from wood - vinsol resin (NVR), before the AEA's are sold to concrete mix plant owners.

One of these tests involves placing an AEA/water mixture in a glass container, stirring or shaking it vigorously, measuring the height of the foam layer created above the water layer, and then measuring the height of the foam one hour-to-four hours later. The acoustic emission emanating from the foam layer during this test may be monitored to continuously define foam stability. The automated foam test instrument disclosed herein may thus provide quantitative foam stability information and important AEA stability information, which is now not possible.

EXAMPLE 2 - WASTEWATER TREATMENT PLANT

In another embodiment, the automated foam index test instrument 10 is used for monitoring and/or controlling foam associated with wastewater treatment, such as in aeration tanks at municipal and industrial

plants. As shown in Figure 3, the sensor 12 and a foam suppressant source 18 are positioned at or near an aeration tank 19 or other holding areas/tanks that receive the wastewater or other foaming liquid. In the preferred embodiment, the controller 16 is positioned at a location remote from the aeration tank 19. For instance, the controller 16 may be located in a separate building at the wastewater treatment site or even remote from the treatment site, such as in another city. Thus, the test instrument 10 "listens" to the foam to provide remote monitoring and process control.

In addition to providing remote monitoring, the test instrument 10 may automatically provide the feedback response necessary to control the wastewater foam without the need for constant monitoring by a human. As previously discussed, the sensor 12 receives the acoustic emissions generated by the foam, including possibly intensities, waveforms, amplitudes, energy, rise time, and frequency of these emissions. In the automated configuration, an operator (such as a wastewater engineer or technician) inputs the desired emission characteristic for the controller 16 to monitor.

For instance, the operator may instruct the controller 16 to record the emission intensity over a period of time. From previous experimentation or mathematical calculation, the operator may set a threshold value representing an excessive foaming condition. At this point, the operator is free to leave the control area since the test instrument 10 will automatically control the foam level. The sensor 12 receives/detects the emissions data and communicates the data to the controller 16. If the controller 16 receives a value approaching or in excess of the preset threshold value, it may excite a

feedback response (such as sounding a visual or audible alarm or dialing a telephone number) or automatically initiate defoaming activity (such as by adding a foam suppressant). Therefore, the foaming may be controlled prior to any deleterious event, such as an overflow.

EXAMPLE 3 - FOAM FLOTATION/FRACTIONATION

In another embodiment, shown in Figure 4, the automated foam index test instrument 10 may be used to provide real time feedback or automated control of a foam fractionation process, such as one involving a liquid column, or any other similar process. Researchers utilize foam fractionation for separating and concentrating proteins and enzymes, such as for recombinant pharmaceutical proteins, and cellulase. Fractionation procedures often vary the pH, concentration, or ionic strength to modify the protein feed solution. Alternatively, to enhance extraction efficiency, the procedures adjust column operational parameters, such as the gas and feed flow rates, foam height, and bubble size. Foam fractionation takes advantage of the surface activity of proteins (e.g., their hydrophobic or hyrophilic nature). As gas, such as air, nitrogen, or carbon dioxide becomes bubbled through a dilute protein solution, surface active proteins adsorb to the gas-liquid interface of the bubbles. The bubbles rise to the top of the liquid pool/column and form a protein rich foam layer. In this foam layer, liquid drains from between the bubbles back into the liquid pool, further concentrating the foam layer. Finally, foam becomes collected and collapsed, resulting in a protein-rich solution.

The automated foam index test instrument 10 characterizes the acoustic emission generated from the bubbles in the liquid layer and from the foam adjacent the top of the corresponding liquid column. As shown in Figure 4, the automated foam test instrument 10 includes sensors 12a, 12b, 12c positioned at the liquid layer 13a, the lower portion of the foam layer 13b, and at the top of the foam layer 13c. The sensor 12a positioned at the liquid layer is a hydrophone which may thus be at least partially submerged.

By measuring the sound pressure, frequency response and spectrum, number of hits, and rise times at these reasons a user may characterize bubble movement, oscillation, and bursts within the liquid. Additionally, the sensor 12 may measure the drainage of the interstitial liquid between bubbles, bubble size/coalescence, and inter-bubble gas diffusion. By measuring and monitoring these variables, the controller 16 may regulate the liquid I_2, gas I_3, and reactant I_4 inputs to the system to increase the protein extraction efficiency.

Figure 8 of ***Exhibit A*** shows acoustic emission data from a liquid feed solution during foam fractionation of a model protein, bovine serum albumin (BSA). This emission data illustrate a distinct difference as the gas flow rate in a 5 cm diameter column increased from 4 to 12 ml/min. Three emission bands were detected in the 0-20,000 Hz region at 1,200 Hz, 1,050 Hz and 600 Hz.

It is known that flow rates between 0-4 ml/min produce high BSA enrichments but low fractionation recoveries; flow rates between 8-10 ml/min provide high enrichments and recoveries, and flow rates above 10

ml/min give low enrichments and high recoveries. As can be seen from Figure 8, the acoustic emission also has three distinct patterns for the flow rates of 0-4 ml/min, 6-10 ml/min, and >10 ml/min. Hence, distinctive acoustic emissions are produced.

EXAMPLE 4 - FOAM CURING/PRODUCTION

In another embodiment, the automated foam index test instrument 10 may be used to monitor and control the heating/curing of high-temperature foams. In one example, a polyimide foam is created by placing a "balloon" precursor material and foaming agent in a furnace. The furnace temperature is then increased and held at a certain temperature or range of temperatures for a given period of time. During heating, the "balloon" precursor material expands and, with the aid of the foaming reagent, creates a polyimide foam consisting of open and closed microspheres. The expansion of the "balloon" may cause bubble breakage, transport of gas between bubbles, and liquid drainage between bubbles. By monitoring the acoustic emissions during this sequence, the automated foam index test instrument 10 may provide real-time monitoring of the foam being formed and provide any necessary feedback control to ensure that the desired end product results.

The foregoing descriptions of various embodiments of the invention are provided for purposes of illustration, and are not intended to be exhaustive or limiting. Modifications or variations are also possible in light of the above teachings. For example, the automated foam index test instrument 10 may any number, type, or placement of sensors 12.

Additionally, the controller 16 may include any device capable of receiving, controlling or processing the sensor data. In addition to the examples disclosed, the automated foam index test instrument 10 may be utilized with any process, system, reactor, or otherwise. Additionally, the provisions for controlling the level of foam may include actuating any response. In addition to the examples of actuating an alarm or a foam suppressant, the test instrument 10 may also control system liquid inlets/outlets, water wash inlets/outlets, aeration connections, mechanical shakers/stirrers, or otherwise. The passive sensor may also form part of a kit including instructions on how to use it in controlling a process with foaming or an object susceptible to foaming. The embodiments described above were chosen to provide the best application to thereby enable one of ordinary skill in the art to utilize the disclosed inventions in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention.

1. An instrument for intended use in monitoring or controlling a foam associated with a process or object, comprising:

a passive sensor for generating an output signal representative of an acoustic emission from the foam; and

a controller in communication with the passive sensor for receiving the output signal and providing a response.

2. The instrument of paragraph 1, wherein the object is a liquid and the response comprises a signal for activating a source of foam suppressant positioned adjacent the liquid.

3. The instrument of paragraph 1, wherein the response comprises a signal for activating an alarm.

4. The instrument of paragraph 1, wherein the response comprises a signal for dialing a telephone number.

5. The instrument of paragraph 1, wherein the response comprises a signal for displaying data representative of the acoustic emissions on a display device.

6. The instrument of paragraph 1, further including a plurality of passive sensors positioned adjacent to the process or object.

7. A system for testing a concrete mixture, comprising:

a vessel for receiving the concrete mixture;

a sensor for measuring an acoustic emission from the concrete mixture and generating output signal; and

a controller in communication with the sensor for receiving the output signal and providing a response.

8. The system according to paragraph 7, wherein the response comprises an activation signal sent to a titrator for adding an air entraining agent to the concrete mixture.

9. The system according to paragraph 7, wherein the response comprises an activation signal sent to an agitator associated with the vessel.

10. The system according to paragraph 7, wherein the sensor is a passive sensor.

11. A foam floatation or fractionation system, comprising:

a column of liquid susceptible to foaming;

at least one input for receiving a flow of gas such that a foam is created on a surface of the liquid column;

a passive sensor for positioning in acoustic communication with the liquid and generating an output signal representative of an acoustic emission from the foam; and

a controller in communication with the passive sensor for receiving the output signals and generating a response.

12. The system according to paragraph 11, wherein the passive sensor is a hydrophone positioned at or below the surface of the liquid column.

13. The system according to paragraph 11, further including a plurality of passive sensors.

14. The system according to paragraph 13, wherein a first of the sensors is positioned above the surface of the liquid and a second of the sensors is positioned at or below the surface of the liquid.

15. An instrument for providing feedback control for a process involving the heating and curing of a foam formed from a precursor material, comprising:

a passive sensor for positioning in acoustic communication with the precursor material and generating an output signal representative of an acoustic emission; and

a controller in communication with the passive sensor for receiving the output signal and generating a response.

16. The instrument of paragraph 15 forming part of a system including a furnace for heating the precursor material.

17. The system of paragraph 16, wherein the response is to control the furnace or to generate a signal to remove the precursor material from the furnace.

18. A method of process control, comprising:

detecting an acoustic emission of a foam; and

actuating a response at a threshold level of the acoustic emission.

19. The method of paragraph 18, wherein the detecting step comprises placing a passive sensor in acoustic communication with the foam.

20. The method of paragraph 18, wherein the step of actuating a response comprises activating a visual or audible alarm.

21. The method of paragraph 18, wherein the step of actuating a response comprises automatically controlling a level of the foam.

22. The method of paragraph 21, wherein the step of automatically controlling the level of the foam comprises adding a foam suppressant.

23. The method of paragraph 18, further including the step of setting the threshold level such that the foaming may be controlled before reaching a predetermined undesirable level.

24. A method of testing concrete, comprising:

adding an agent to one or more components to form a mix;

detecting one or more acoustic emissions of the mix; and

determining whether an additional amount of the agent is required.

25. The method according to paragraph 24, wherein the agent is an air entraining agent and the step of measuring comprises measuring the acoustic emissions from a foam created on the surface of the mix.

26. A method of creating a concrete mix, comprising:

adding an agent to a sample of the concrete mix;

measuring the acoustic emissions of the mix;

determining whether to add an additional amount of the agent; and

when an appropriate amount of the agent is added, creating a larger batch of the mix by adding an amount of the agent proportional to the amount added to the sample.

27. The method according to paragraph 26, wherein the agent is an air entraining agent and the step of measuring comprises measuring the acoustic emissions from a foam created by the mix.

28. A method of testing the efficacy of an air entraining agent, comprising:

agitating the agent to create a foam;

detecting one or more acoustic emissions of the foam; and

determining whether the agent remains effective.

29. A method of treating wastewater, comprising:

measuring an acoustic emission of a foam associated with the wastewater; and

actuating a response at a threshold level of the acoustic emission.

30. The method of paragraph 29, wherein the step of measuring comprises placing a passive sensor in acoustic communication with the foam.

31. The method of paragraph 29, wherein the step of actuating a response comprises activating a visual or audible alarm.

32. The method of paragraph 29, wherein the step of actuating a response comprises automatically controlling a level of the foam.

33. The method of paragraph 29, wherein the step of automatically controlling the level of the foam comprises adding a foam suppressant.

34. A method of controlling a foam fractionation, foaming, or flotation process, comprising:

measuring an acoustic emission generated by the foam adjacent the top of the column;

actuating a response at a threshold level of the acoustic emission.

35. The method according to paragraph 34, further including the step of regulating an air input to the column.

36. The method according to paragraph 34, wherein the step of measuring the acoustic emissions comprises providing an at least partially submerged hydrophone.

37. A method of controlling the heating/curing of a foam, comprising:

heating a precursor material including a foaming agent;

measuring an acoustic emission from the precursor material; and

actuating a response at a threshold level of the acoustic emission.

38. The method of paragraph 37, wherein the step of actuating a response providing a signal to remove the precursor material from a furnace.

39. A kit, comprising:

a passive acoustic sensor; and

instructions for using the sensor for monitoring or controlling a process involving foaming or an object susceptible to foaming.

40. The kit of paragraph 39, wherein the process is the method of any one of paragraphs 18-38.

Abstract of the Disclosure

The present invention involves monitoring, detecting or measuring one or more acoustic emissions of a foam using a passive sensor. The detected emission(s) may then be used to generate a response, such as one to control an associated process. Corresponding methods, systems, and test instruments are also disclosed, as is a kit including a passive sensor and instructions for using it in conjunction with a foaming object or process.

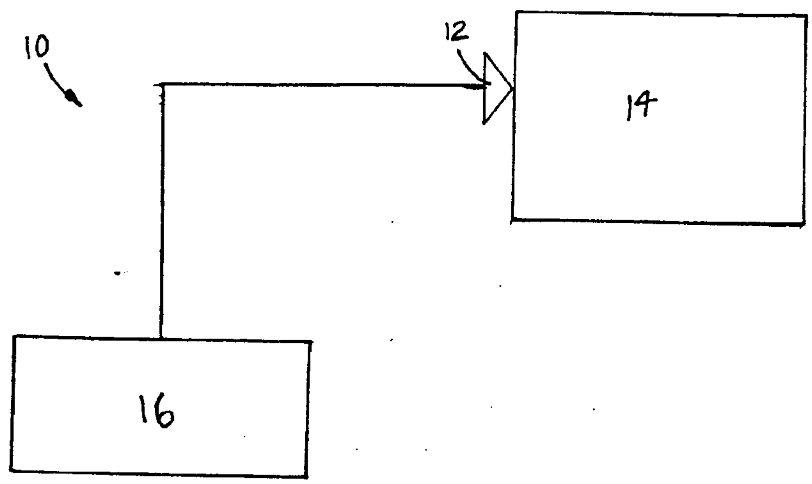

FIG. 1

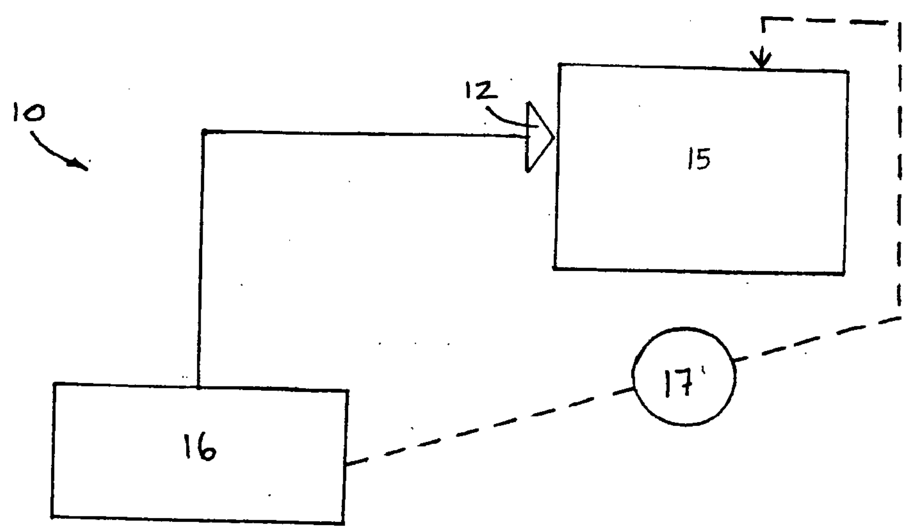

FIG. 2

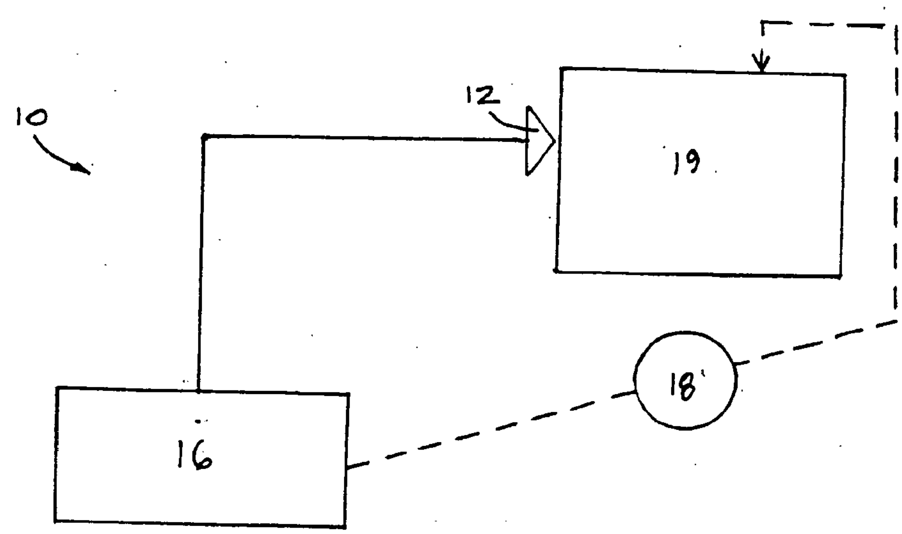

FIG. 3

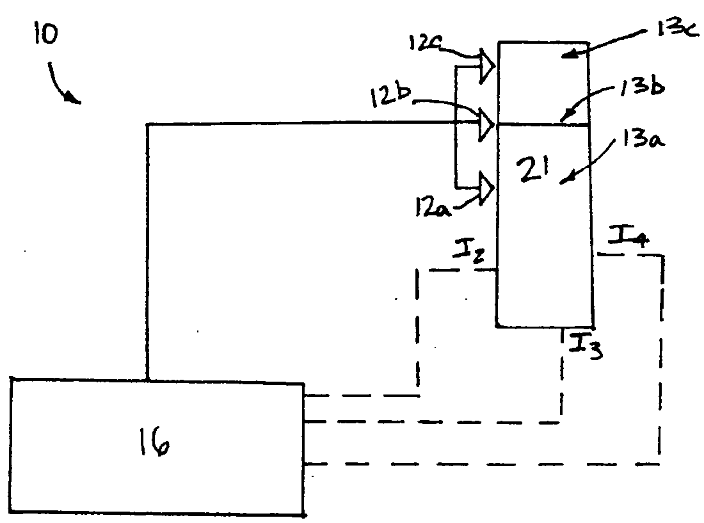

FIG. 4